Saskatchewan
Agriculture

Natural Air Grain Drying

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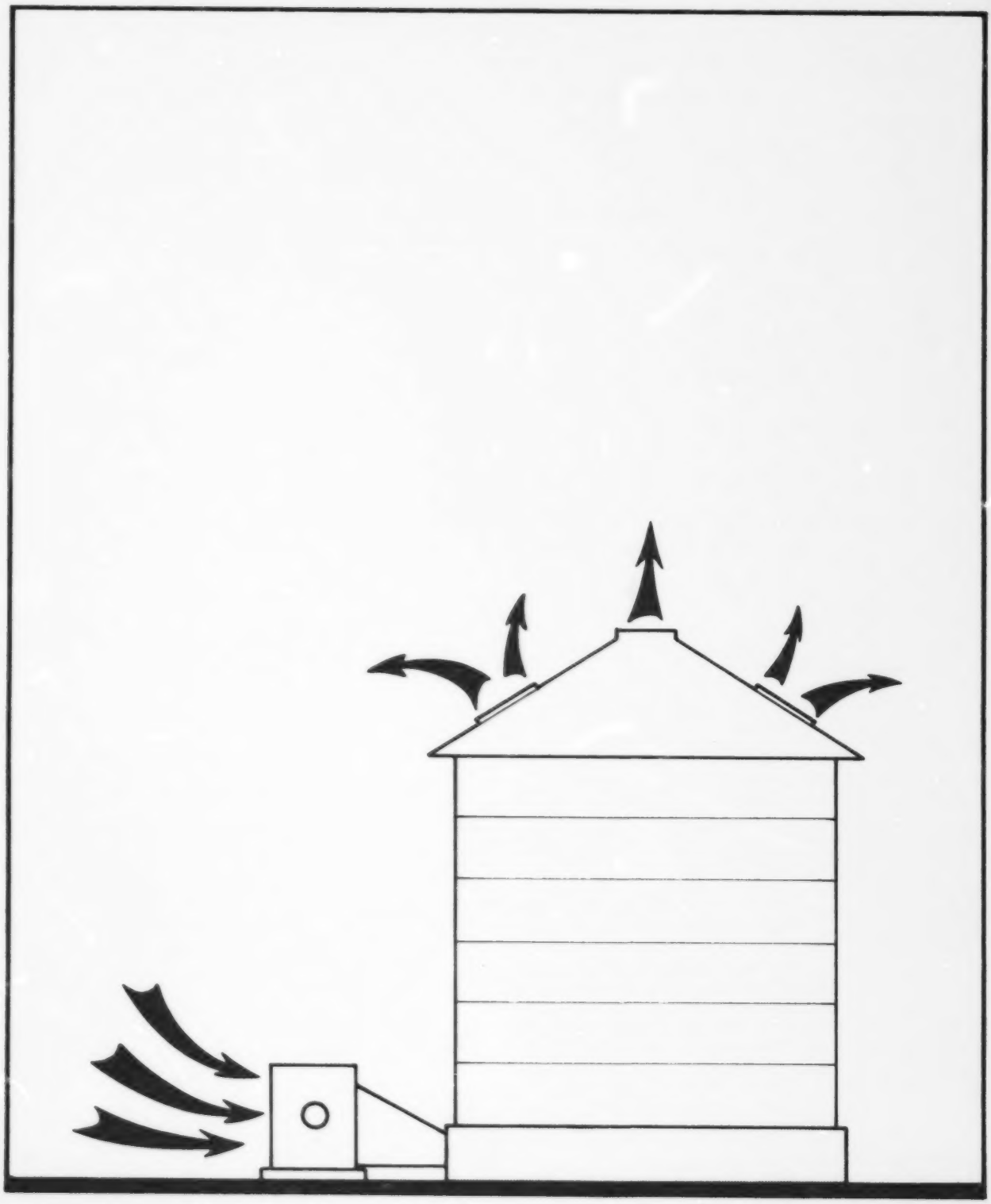

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Natural Air Grain Drying

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In this publication, imperial units are used as the primary units of measurement. The SI (metric) units in brackets are not necessarily exact conversions, but are equivalent practical conversions and are values that would be used if the SI system was used alone.

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Introduction

To complete harvest as quickly as possible, with the lowest possible crop loss and with minimal cash costs, many farmers have, or are considering,natural air drying.

Natural air drying differs from hot air drying in many ways, yet it may accomplish the same end result if the user understands the process and its limitations.

The main advantages of natural air grain drying are flexibility and low operation costs. The disadvantages include its reliance on ambient air conditions, extended operating time and the associated grain handling requirements.

When considering natural air drying, it is also necessary to contact the Saskatchewan Power Corporation to ensure that adequate electrical power is available at the site.

Principle of Operation

Natural air grain drying works on the principle that when the moisture content (m.c.) of the grain is greater than the equilibrium moisture content (Fig. 1), moisture will move from the grain into the air until equilibrium is reached. The lower the relative humidity (R.H.) of the air, the lower the equilibrium moisture content. Equilibrium moisture content is the condition when there is no movement or transfer of moisture between the grain and air. Figure 1 gives the approximate equilibrium moisture contents for cereal grains and for oil seeds.

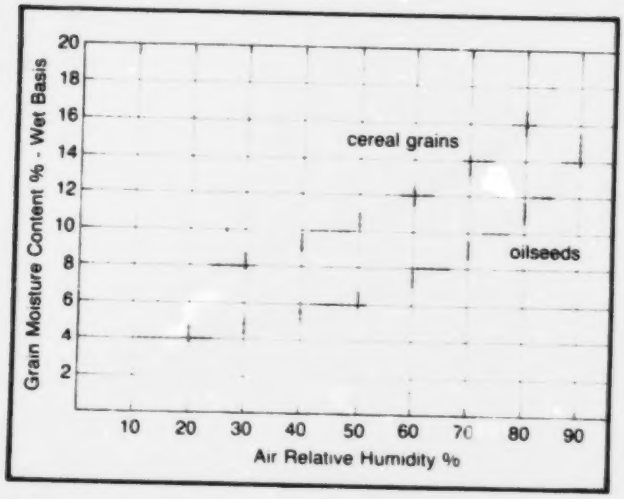


Figure 1. Equilibrium moisture content of grains

Figure 2 shows the allowable storage time for grains without forced air movement through the grain mass. Airflow through the grain, as with aeration or natural air grain drying, will increase the allowable storage time.

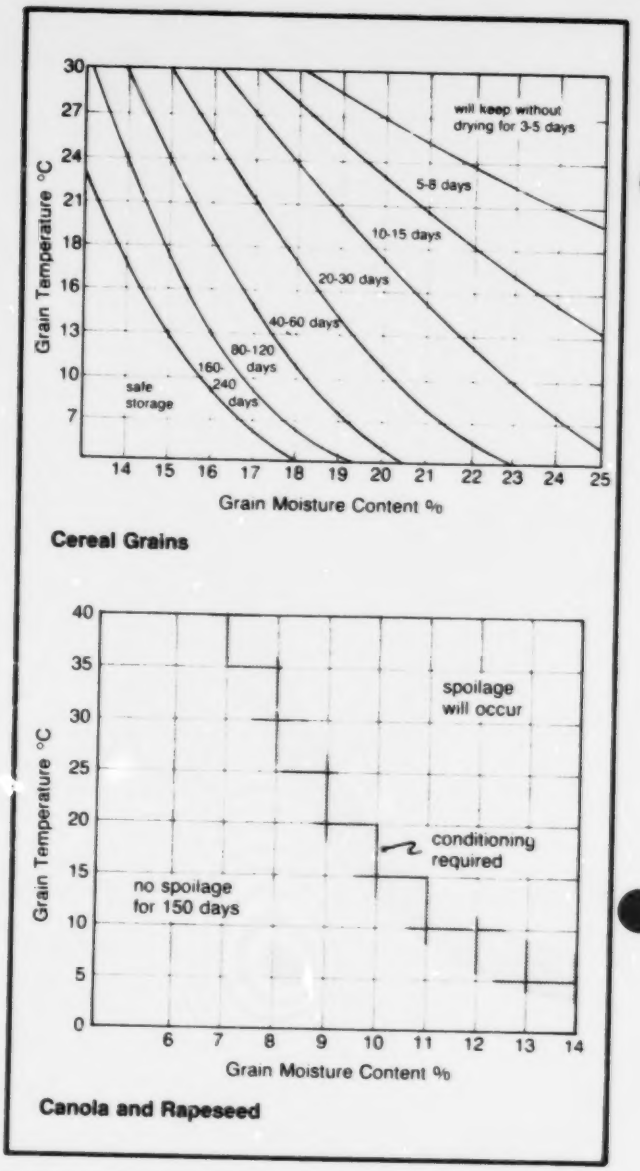


Figure 2. Storage time for grsins at various temperatures and moisture contents

Figure 2 also illustrates that the combination of high grain moisture content and high grain temperature drastically reduces the allowable storage time and the allowable time for drying. Under these conditions, it is critical that the natural air drying system have the capability to complete the drying process before the grain begins to spoil.

Operation

When using natural air drying as an integral component of an overall harvesting system, harvest should begin when the grain reaches 18-20 percent m.c. Thus, maximum advantage may be taken of the low relative humidity which normally occurs in late August and early September.

Natural air drying should not be considered as an emergency drying system.

The grain placed in the drying bin should be relatively clean. Fines, chaff, small or broken seeds and weed seeds increase the grain's resistance to airflow. Fines also tend to accumulate in the center of the bin and may spoil due to a lack of conditioning.

The use of a grain spreading device in large diameter bins is recommended. These devices will help in distributing the grain, including fines, evenly in the bin. The grain surface should be kept level, or if possible, with a slight dish in the center. The above conditions will result in more uniform conditioning due to an even airflow through the entire grain mass. If the grain is clean, a spreading device may not be necessary provided the grain is manually leveled.

The fan should be started when the perforated flooring or tubes are completely covered with grain. Grain should be checked frequently to determine the location and the rate of movement of the drying front.

Checking should continue after the fan has been stopped and when the grain has been transferred to another bin. The grain may still need to be aerated just as if it had been harvested dry (see publication "Aeration of Grain in Storage" available from the local agricultural representative). During winter, check the top center 1 to 3 ft. (300 to 900 mm) of grain for moisture buildup or for an increase in temperature.

Air, forced through from the bottom, picks up moisture and carries it out through openings in the top of the bin (Fig. 3). Grain above the drying front remains at or near its initial moisture content. Grain within the drying front is between the initial moisture content and equilibrium moisture content. Grain below the drying front has a moisture content at or near the equilibrium moisture content.

The key to natural air drying is to move the drying front through the grain as quickly as possible. Actual times may vary from one to six weeks.

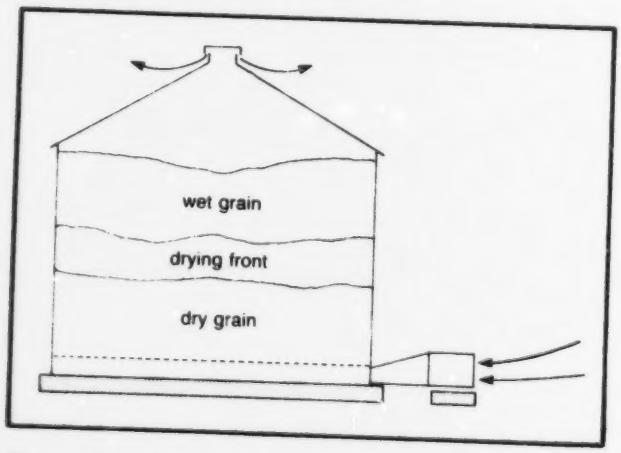


Figure 3. In-bin natural air drying

Management of Natural Air Grain Drying Systems

The flexibility of natural air grain drying systems will allow the operator to manage the system in several ways. Improper management usually results in lost income, not lost grain due to spoilage.

The term "dry" defines the maximum moisture content at which the Canadian Wheat Board buys grain without penalty and is the moisture content at which grain can be safely stored for long periods of time. The "dry" moisture content for various grains are:

wheat - 14.5%
barley - 14.8%
oats - 14.0%
rye - 14.0%
flax - 10.5%
canola (rapeseed) - 10.0%
mustard - 10.5%
lentils - 14.0%

The fan(s) should be started when the perforated flooring or tubes are completely covered with grain. Be sure enough grain is on the flooring to hold it in place when the fan is turned on. The fan should then be operated continuously until one of the following situations occur:

a. Drying Front is Completely Through the Grain Mass

In this case, the fan has been operated continuously until the drying front has been forced through the grain mass. The grain at the bottom will dry to the equilibrium grain moisture content, which may be in the 10 to 11 percent range before the top reaches 14.5 percent. Some rewetting of the bottom layer may occur during evenings or wet rainy spells, but a moisture content variation, similiar to that shown in Figure 4, still results.

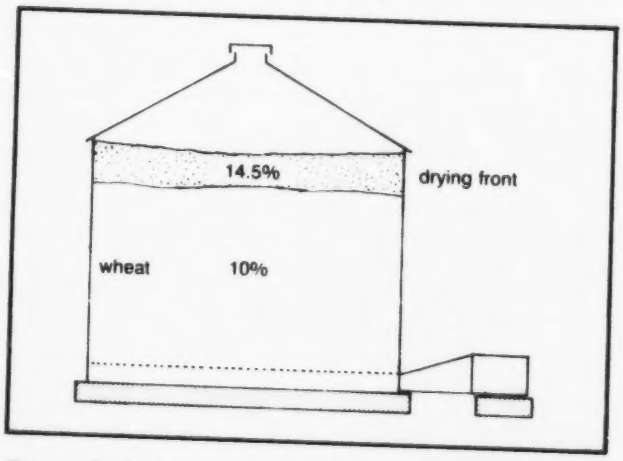


Figure 4. Drying front completely through the grain mass

When managing a natural air grain drying system in this manner, a substantial loss in saleable product weight may result. For example, about 4200 lb. (1.9 t) of saleable water is removed from a 19 ft. (5.9 m) diameter by 14 ft. (4.3 m) high bin containing 3280 bu. (89.4 t) of wheat, by drying the complete grain mass to an equilibrium moisture content of 12.5 percent. At $4.00/bu. ($147.00/t), this amounts to $280 of lost revenue plus the cost of operating the fan longer.

b. Drying Front is Partially Through the Grain Mass

This case is similiar to a. except the fan is stopped before the drying front is pushed completely through the grain mass (Fig. 5). The bottom layers are below dry, but the upper layers are still above dry. At this stage, the grain is mixed. Moving the grain from one bin to another storage bin may mix the below-dry and the above-dry grain. After a period of time, the moisture contents equalize, hopefully at "dry". Experience will be required to determine when the fan should be stopped and the grain moved. The grain should be probed to determine if aeration is required.

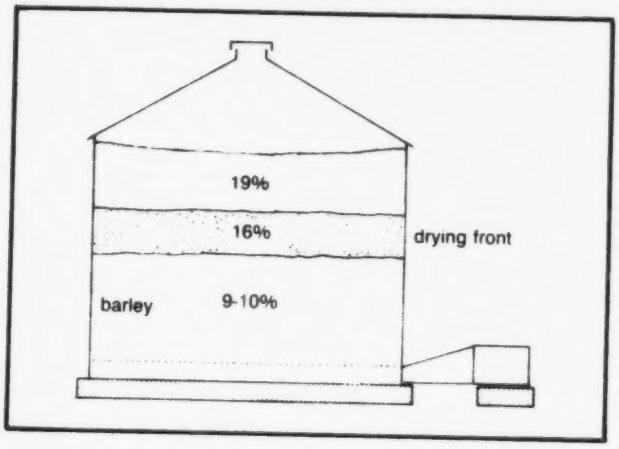


Figure 5. Drying front partially through the grain mass

In both cases, a. and b., the operator must know the grain condition and what effect the flow of ambient air will have on the grain. This information will allow the operator to decide if the fan should be operating.

For example, barley at 19 percent m.c. was harvested in late August when ambient conditions are 30°C and 40 percent R.H. The fan was started as soon as the flooring was covered. The drying front has moved part way through the grain mass.

After several days of continuous fan operation, the grain condition is similar to Figure 5. The weather now turns to 20°C and 90 percent R.H.

The grain mass will be cooled to 20°C and the lower section (9 percent grain) will begin to take on some moisture. Both changes are desirable. The upper grain (19 percent m.c.) will not change as the equilibrium moisture content at 90 percent R.H. is approximately 20 percent. It has been shown that grain re-wets at a much slower rate than it dries.

If the high humidity conditions continue for more than two or three days, it would be advisable to turn the fan off as little is gained by allowing it to run longer. Barley will safely store for about 20 days at 20°C and 19 percent m.c. (Fig. 2). The grain should be probed and checked for trouble spots.

c. Drying Front is Partially Through the Grain Mass and the Entire Grain Mass Temperature is -5°C

This situation occurs when weather conditions are unfavorable and there is insufficient time to move the drying front through the grain as described in b. The fan must be allowed to run to drop the grain temperature to below freezing. This prevents the grain from heating and/or spoiling during the winter months. The entire bin may be left frozen until spring or dried in a hot air dryer.

Drying with Supplemental Heat

The fall of 1985 illustrated that the drying rate of a natural air grain drying system can be slowed or completely stopped by adverse weather conditions. Using supplemental heat can result in the continuation of drying but there are disadvantages.

The reasons that the drying rate reduces are: cool air can only hold a small amount of moisture and moisture movement from grain to air is very slow at temperatures less than 10°C.

Adding heat to the inlet air results in a higher air temperature which reduces its relative humidity, and a higher grain temperature which increases the rate of moisture movement. These results increase the drying rate. A rule of thumb relating temperature increase to relative humidity decrease is: a temperature increase of 10°C reduces the relative humidity by one-half. For example, air at 0°C and 70 percent relative humidity heated to 10°C results in a relative humidity of 35 percent; an additional 10°C rise to 20°C reduces the relative humidity to 17 percent.

If supplemental heat is used, it is recommended that the temperature increase be limited to 10°C and that the heater has, at least, the following safeguards: a) a maximum temperature cutoff, and b) a minimum airflow cutoff.

The following formula can be used to size a supplemental heater or to determine the approximate temperature rise that can be expected from a particular heater.

Heater Output = Change in temperature x airflow x constant

Btu/hr = Δt(°F) x cfm x 1.1

Watts = Δt(°C) x L/s x 1.2

The disadvantages of using supplemental heat are:

- increased costs (capital and operating)

- possible condensation on bin walls

- possible grain contamination if combustion air from diesel or furnace fuel fired units is forced through the grain mass

- overdrying costs may increase, especially if a temperature rise greater than 10 degrees is used or if low airflow rates are used.

Costs Resulting From Selling Grain Other Than "Dry"

It is well known that there is a penalty for selling grain at a moisture content other than "dry." For example, in the 1985-86 crop year, the penalties for selling tough and damp wheat were 19¢/bu. ($7/t) and 39¢/bu. ($14.50/t) respectively. The penalty for selling below "dry" grain varies directly with the moisture content. Lowering the water content reduces the weight of the grain mass being sold. Penalties may be minimized if the grain is blended to average "dry."

Table 1 illustrates the value of wheat at various moisture contents.

Tools Required for Monitoring a Natural Air Grain Drying System

When setting up a natural air grain drying system, the following tools should be considered essential:

Grain probe - used to obtain grain samples for determining moisture content. It is not easy to push a probe into 15 ft. (4.5 m) of tough grain. Probes vary in size and shape. Normally a long, thin, tapered design is the easiest to operate for sampling. Probes with large flightings must be augered in and out. The capacity of the probe should be large enough that only one sample is required for the moisture meter.

Grain moisture meter - used to determine the grain moisture content which is necessary information for proper management of the system. Check PAMI reports regarding the performance of moisture meters.

Manometer - used to measure the static pressure developed by grain in a bin when forcing air through the grain. Manometers may be purchased or made. A manometer consists of a transparent tube, with a minimum inside diameter of 1/4 in. (6 mm), bent into a "U" shape and a ruler; all mounted on a board (Fig. 6). The tube is filled with water to the level shown in Figure 6. One end of the tube is left open, the other end is connected to the transition.

Table 1. Value of wheat at various moisture contents.

Moisture content %	No. of Bushels per 1000 @ 14.5%	Price per bushel*	Total grain return	Penalty difference
10	950	$4.00	$3800.00	$ - 200.00
12	972	4.00	3888.00	- 112.00
14.5	1000	4.00	4000.00	—
16	1018	3.81	3878.58	- 121.42
18	1043	3.61	3765.23	- 234.47
Moisture content %	**No. of tonnes per 30 t @ 14.5%**	**Price per tonne***	**Total grain return**	**Penalty difference**
10	28.5	$147.00	$4189.50	$ - 220.50
12	29.15	147.00	4285.05	- 124.95
14.5	30	147.00	4410.00	—
16	30.55	140.00	4277.00	- 133.00
18	31.3	132.50	4147.25	- 262.75

*Based on a grain price of $4.00/bu ($147.00/t) and penalties of 19¢/bu ($7/t) and 39¢/bu ($14.50/t) for tough and damp respectively.

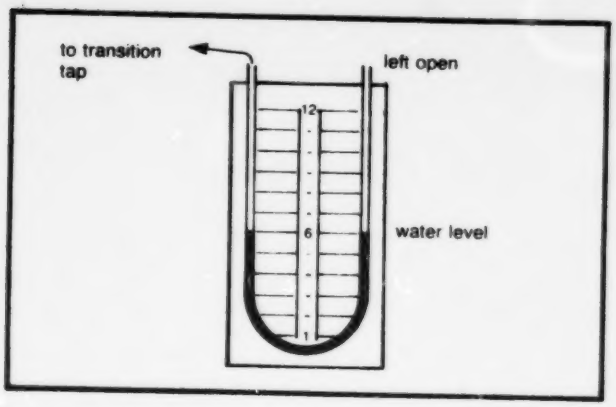


Figure 6. Manometer

Table 2. Recommended air flow rates for various grain moisture contents and temperatures.

% Moisture Content Above Dry	Air Flow Rate: Grain Temp. Low→High	Air Flow Rate: Grain Temp. Low→High
	cfm/bu	L/s•m³
→4	0.5 →0.75	7 →10
4→6	0.75 →1.0	10 →13
6→8	1.0 →1.5	13 →20

Factors to be Considered in System Design

When selecting the equipment for a natural air grain drying system, several points must be considered.

Location

The location of the farm must be considered since the weather conditions vary within the province. Considering this factor, the province has been divided into three zones (Fig. 7).

In Zone 1, the airflow rates given in Table 2 apply. In Zone 2, the rates will have to be increased by 1.25 times. The increased rates are required due to the higher relative humidity in Zone 2.

There are more risks involved in using natural air grain drying in Zone 3 because the mean relative humidity for September is above 70 percent. Drying is possible (Fig. 1), but the time required will be longer. If natural air drying is used in Zone 3, the grain should be monitored closely and the airflow rates will have to be increased by 1.5 times.

Grain Moisture Content and Temperature

The maximum expected moisture content of grain to be harvested will partially determine the required airflow rate. Grain with a high moisture content will require a greater airflow rate than grain with a lower moisture content. The greater airflow rate is necessary to increase the drying rate so that the grain is conditioned before it begins to spoil.

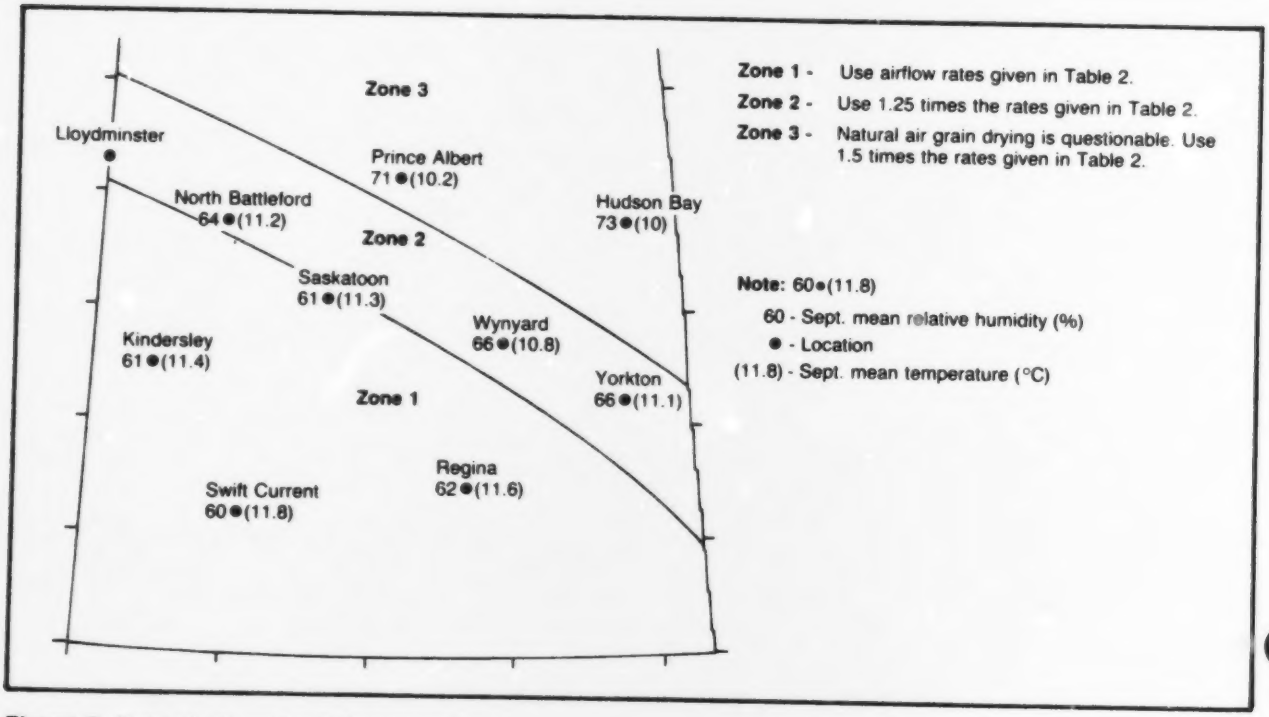


Figure 7. Natural air grain drying zones

Grain temperature also influences the airflow rate. Grain put into the bin with a high temperature will require a higher airflow rate. This higher airflow rate is necessary to quickly reduce the grain temperature before it begins to spoil.

Figure 2 illustrates the safe storage times for grains at various moisture contents and temperatures. Table 2 provides the recommended airflow rates for various grain moisture contents and temperatures. The higher airflow rates should be used for grain above 22°C.

Grain Type and Depth

The type of grain to be dried will affect the static pressure developed and thereby the fan required. Grains with small seeds create a higher resistance to airflow and a resulting higher static pressure.

The grain depth will also effect the static pressure, the greater the depth, the greater the static pressure. Figure 8 gives the expected static pressures for various depths and for different grains based on seed size. This information is also provided in tabular form in Appendix 3.

Natural Air Drying Equipment

Satisfactory performance of a natural air drying system depends upon the selection, installation and management of equipment. The following must be considered to ensure satisfactory performance.

Bin Selection

Figure 9 illustrates two bins which contain the same amount of grain. The difference in grain depths is due to the difference in bin diameters. Both bins will require the same airflow, but will require different fans to deliver this airflow.

The deeper grain mass results in a higher static pressure and, consequently, a higher powered fan. In an attempt to keep the static pressure as low as possible, low, large diameter bins should be selected for natural air drying systems.

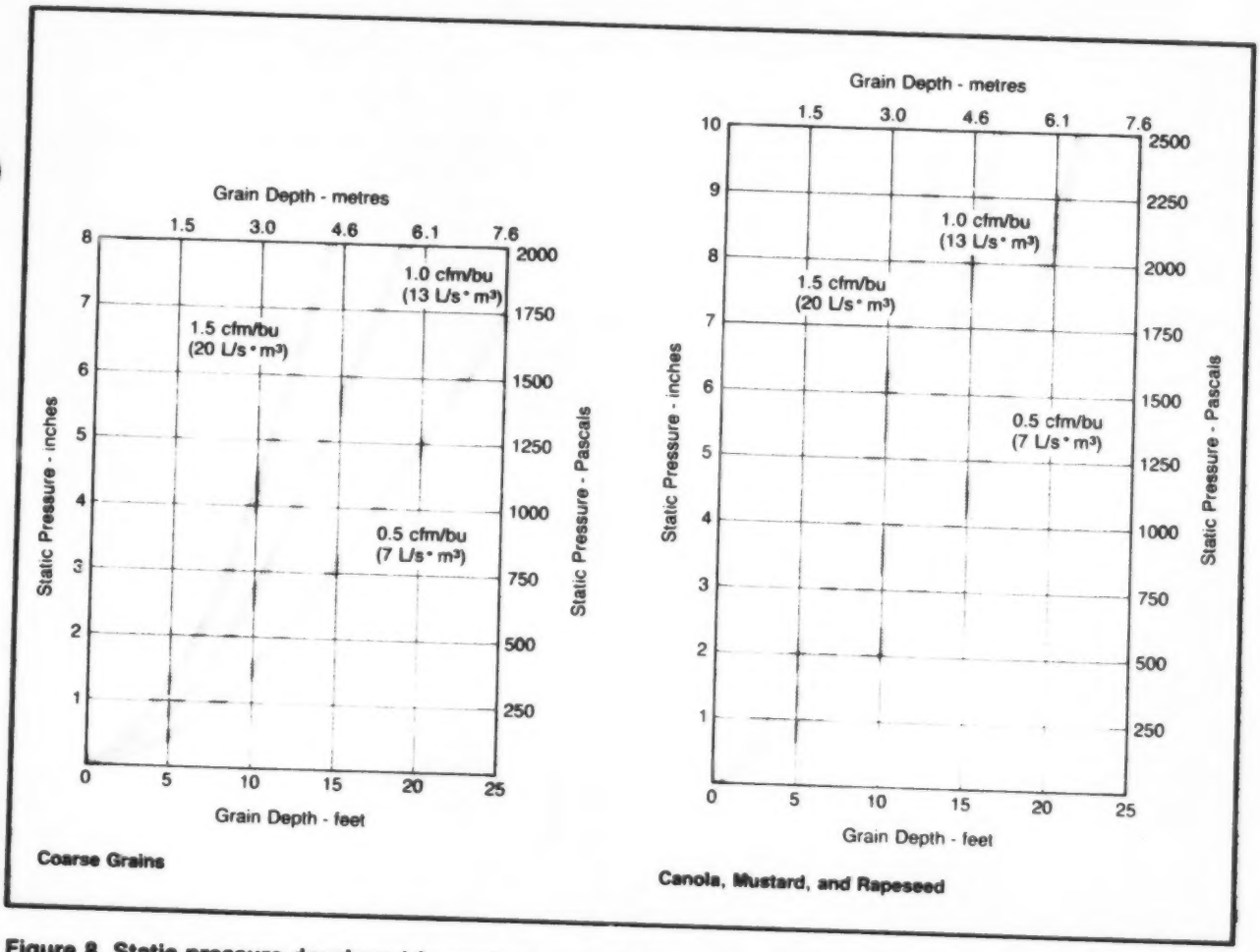
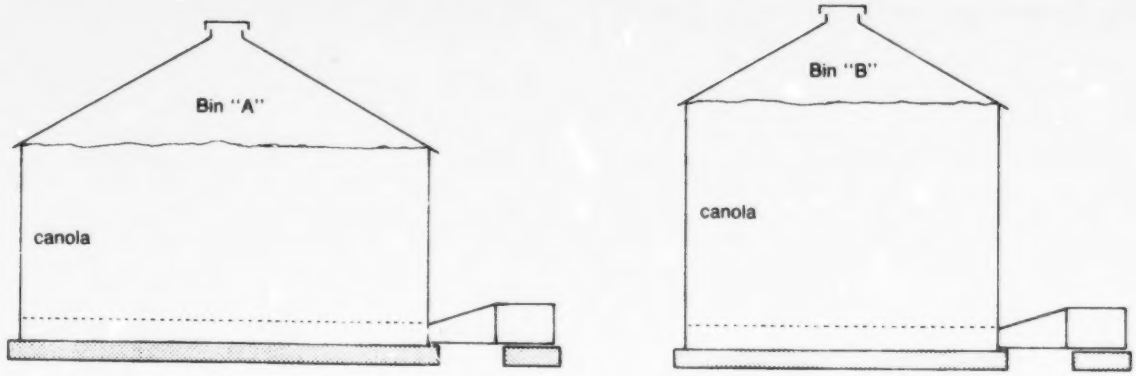


Figure 8. Static pressure developed for various grain depths and airflow rates



Example:	Bin "A"	Bin "B"
Diameter	22 ft. (6.7 m)	18 ft. (5.5 m)
Grain depth	10 ft. (3.1 m)	15 ft. (4.5 m)
Grain volume	3000 bushels (110 m^3)	3000 bushels (110 m^3)
Expected static pressure @ 0.75 cfm/bu (10 L/s•m^3)	3.5 in. (875 Pa) @ 2250 cfm (1100 L/s)	7.5 in. (1875 Pa) @ 2250 cfm (1100 L/s)
Typical fan required	5 hp (3.73 kW) axial or 3 hp (2.24 kW) centrifugal	5 hp (3.73 kW) centrifugal (beyond the range of an axial fan)

Figure 9. Grain bins of equal volume but different diameters

Fan Selection

The fan selected (Fig. 10) must be able to deliver the desired amount of air at the expected static pressure. Consult the manufacturer's specifications and independent fan test reports for fan performance.

Centrifugal type fans should be considered when static pressure exceeds 4 in. (1000 Pa) (Fig. 11) or if operating noise is a consideration.

In-line centrifugal fans have performance characteristics similar to conventional centrifugal fans. The in-line centrifugal fan's main advantages are lower cost and it can bolt directly to transitions made for axial fans (Fig. 12).

Vane axial fans are more efficient than tube-axial fans. Externally they look identical; however, vane-axial fans have internal vanes which catch and direct the air as it leaves the fan blades (Fig. 13).

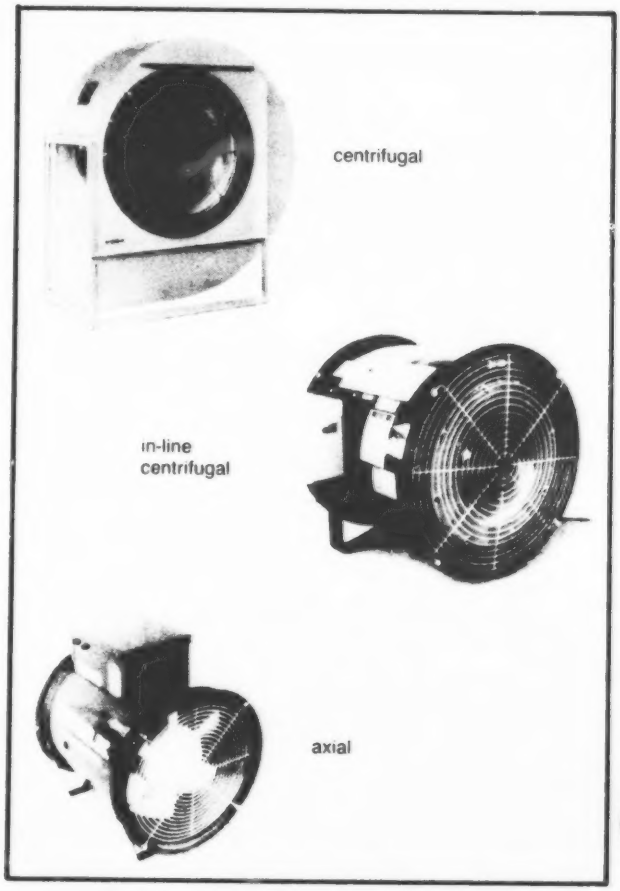


Figure 10. Natural air grain drying fans

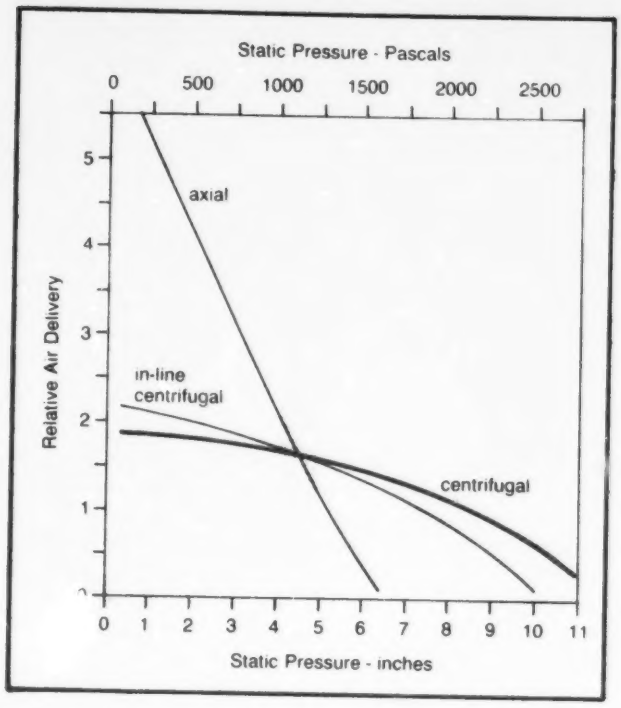


Figure 11. Comparison of equal powered fans

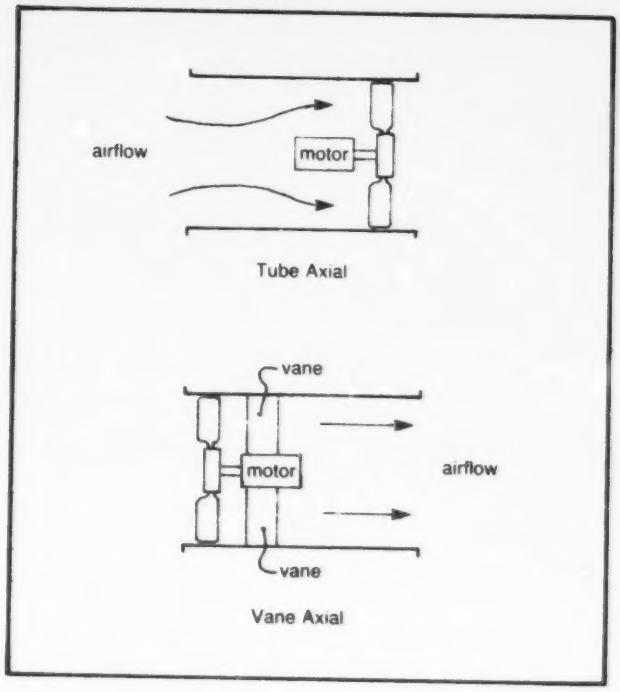


Figure 13. Tube and vane axial fans

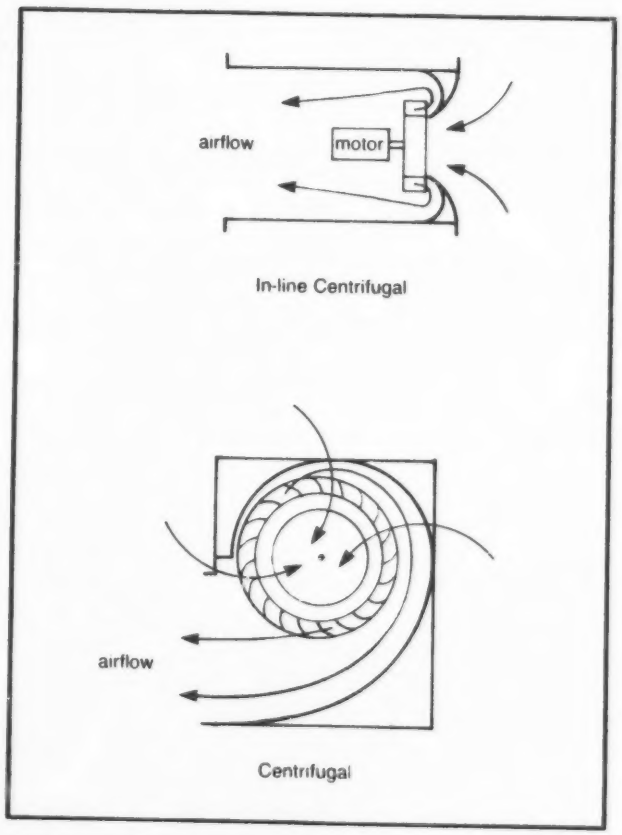


Figure 12. In-line centrifugal and centrifugal fans

It is advisable to have a manometer mounted on each bin to measure the static pressure developed. By matching the fan output to the grain volume, the desired airflow rate (cfm/bu. or L/s • m^3) may be achieved.

Difficulties have been encountered in accurately measuring the static pressure at the transition. To overcome the possibility of inaccurate readings, one of the following methods is recommended:

1) place a length of tubing extending near the center of the bin in or under the perforated material (Fig. 14). Connect one end to the manometer. If the transition is short and abrupt ("A" Fig. 15), add 1 in. (250 Pa) to the manometer reading to give static pressure at the fan. If the transition is relatively long and tapered ("B" Fig. 15), add 1/2 in. (125 Pa) to the manometer reading.

2) drill a series of holes in the transition as shown in Figure 15. Two holes at 90 degrees to each other is a minimum, four holes is preferred. Individual manometer readings should be averaged or the holes may be joined by using "T's" and one reading taken. If possible, drill these holes large enough to install valve stems (without the valve) and keep capped when not in use.

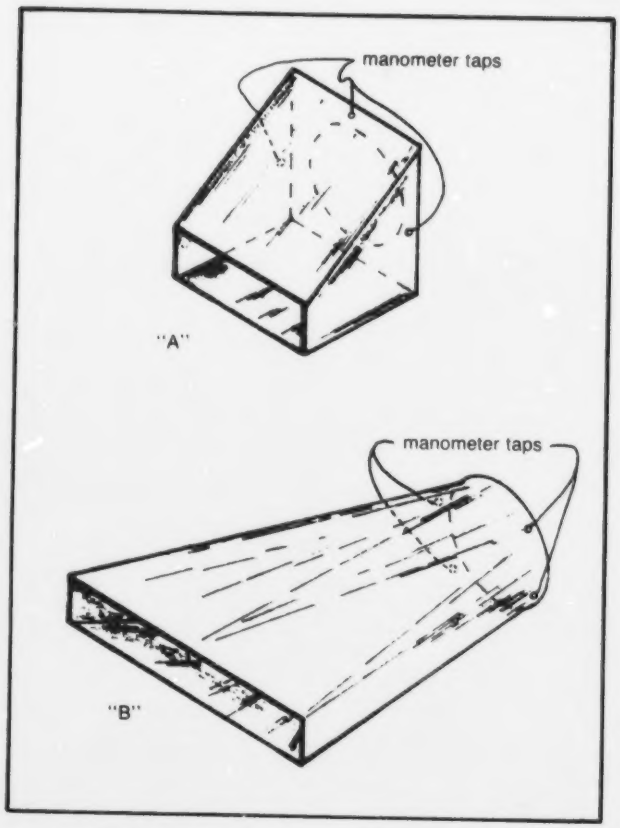


Figure 15. Typical transitions

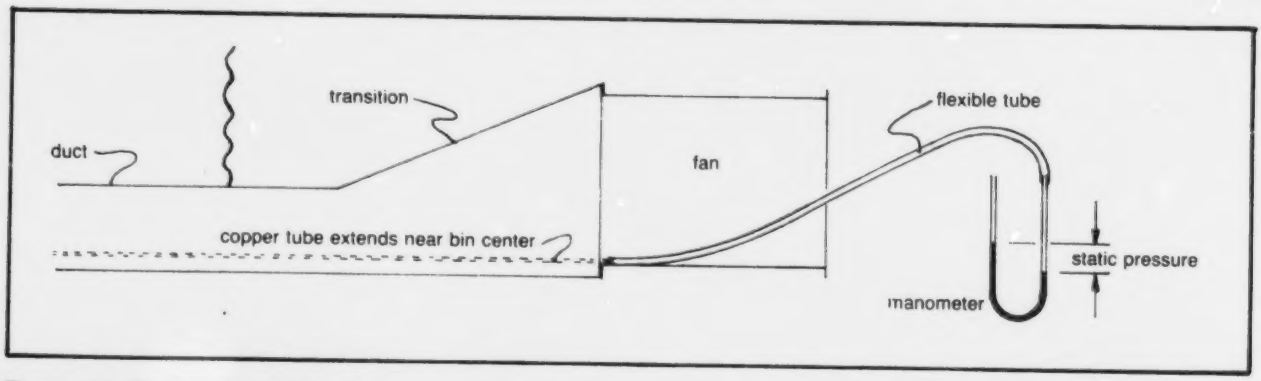


Figure 14. Manometer installation

Sizing of Transitions, Ducts, Vents and Perforated Floor Area

The transition from the fan assembly to the duct should be as smooth as possible. Abrupt changes in transition cross-section should be avoided. Transition "B", in Figure 15, is more desirable than Transition "A". Skilled sheet metal workers are capable of fabricating this type of equipment. The duct size required may be determined from the following, or from Table 3.

$$\text{Cross-sectional area} = \frac{\text{total air volume}}{\text{*maximum duct air velocity}}$$

$$\text{Cross-sectional area (ft}^2\text{)} = \frac{\text{total air volume (cfm)}}{1500}$$

$$\text{Cross-sectional area (m}^2\text{)} = \frac{\text{total air volume (L/s)}}{7500}$$

* maximum duct velocity = 1500 fpm (7.5 m/s)

The vent area in the bin roof should be approximately 1.5 times the duct cross-sectional area.

Selection of Perforated Material

The perforations in the ducts and/or flooring must be sized to prevent the seed from passing through and yet large enough to offer the least possible resistance to the airflow through the perforations.

The material should be at least 10 percent perforated. Consult the various suppliers and manufacturers of perforated material to determine the one(s) most suitable. The perforated floor area should be sized such that the air velocity through this total area is 30 ft./min. (0.15 m/s) or less. Actual velocity of air through a perforation will be 300 ft./min. (1.5 m/s) with 10 percent perforated material.

Layout of Perforated Ducts and Flooring

The layout of perforated material should provide as uniform as possible air distribution to the grain mass. Uniform air distribution is necessary when drying high moisture grain, grains at high temperatures, or when using high airflow rates. Refer to Saskatchewan Agriculture Plan S-711 for foundation plans, available from the regional farmstead engineer.

Flush Floor Systems

The fully perforated floor is the most desirable layout for a natural air drying system, but is the most costly and, in some cases, not necessary. Fully perforated floors may be installed in existing bins.

Fully perforated floors usually consist of perforated planking on manufactured supports, perforated sheet or roll material on either manufactured supports or user supplied supports. The distributor or supplier of the perforated material should be consulted regarding the support required.

Partially perforated floors, as illustrated in Figure 16, are being successfully used. The recommended maximum moisture content of the grain being dried with this system is 6 percent above dry.

Partially perforated floors are normally installed in new bins, however retrofitting an existing bin is possible.

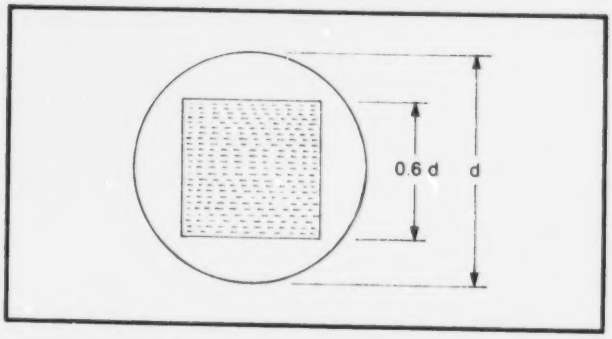


Figure 16. Partially perforated floor

Table 3. Sizing of transitions, ducts, perforated floor area, and vents.

Air Flow		Minimum Cross-Sectional Duct Area		Perforated Floor Area		Minimum Roof Vent Area	
cfm	L/s	ft²	m²	ft²	m²	ft²	m²
500	250	0.33	0.03	17.0	1.7	0.5	0.05
1 000	500	0.67	0.07	33.0	3.3	1.0	0.1
1 500	750	1.0	0.1	50.0	5.0	1.5	0.15
2 000	1 000	1.33	0.13	67.0	6.7	2.0	0.2
2 500	1 250	1.67	0.17	83.0	8.3	2.5	0.25
3 000	1 500	2.0	0.2	100.0	10.0	3.0	0.3
3 500	1 750	2.33	0.23	117.0	11.7	3.5	0.35
4 000	2 000	2.67	0.27	133.0	13.3	4.0	0.4

Above Floor Systems

The tube or half-round perforated systems (Fig. 17) are commonly used in existing bins. The maximum recommended grain moisture content of the grain being dried with this system is 4 percent above dry. This moisture content may be increased by using a "Y" or "T" system of ducts to obtain a more uniform air distribution.

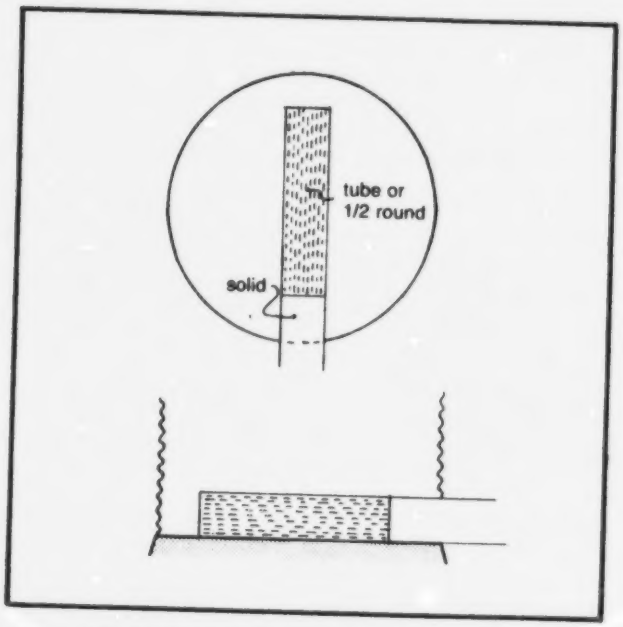


Figure 17. Tube or half-round system

The inverted "V" system (Fig. 18) is another above floor system, but does not use any perforated material. The maximum moisture content of the grain being dried will depend on the duct layout.

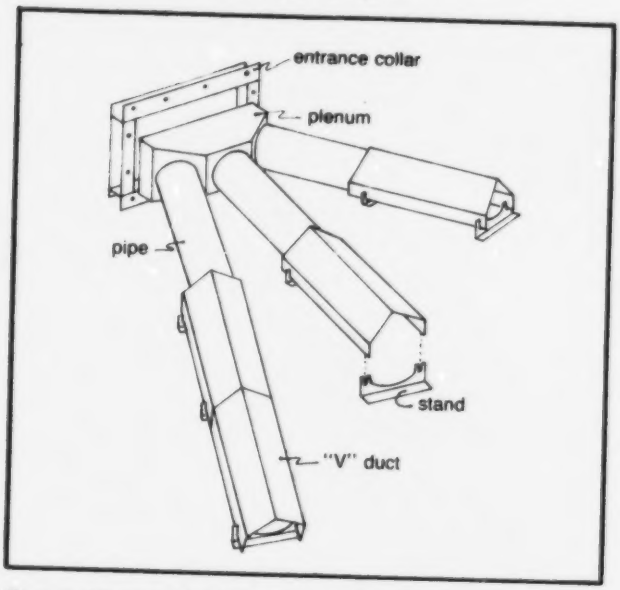


Figure 18. Inverted "V" system

Figure 19 illustrates a design suitable for a 12 x 14 x 8 ft. (3.6 x 5.2 x 2.4 m) wood grain bin at an airflow rate of 1 cfm/bu. (13 L/s • m³).

All of the above floor systems must be moved or removed when the bin is being emptied or when a sweep auger is being used.

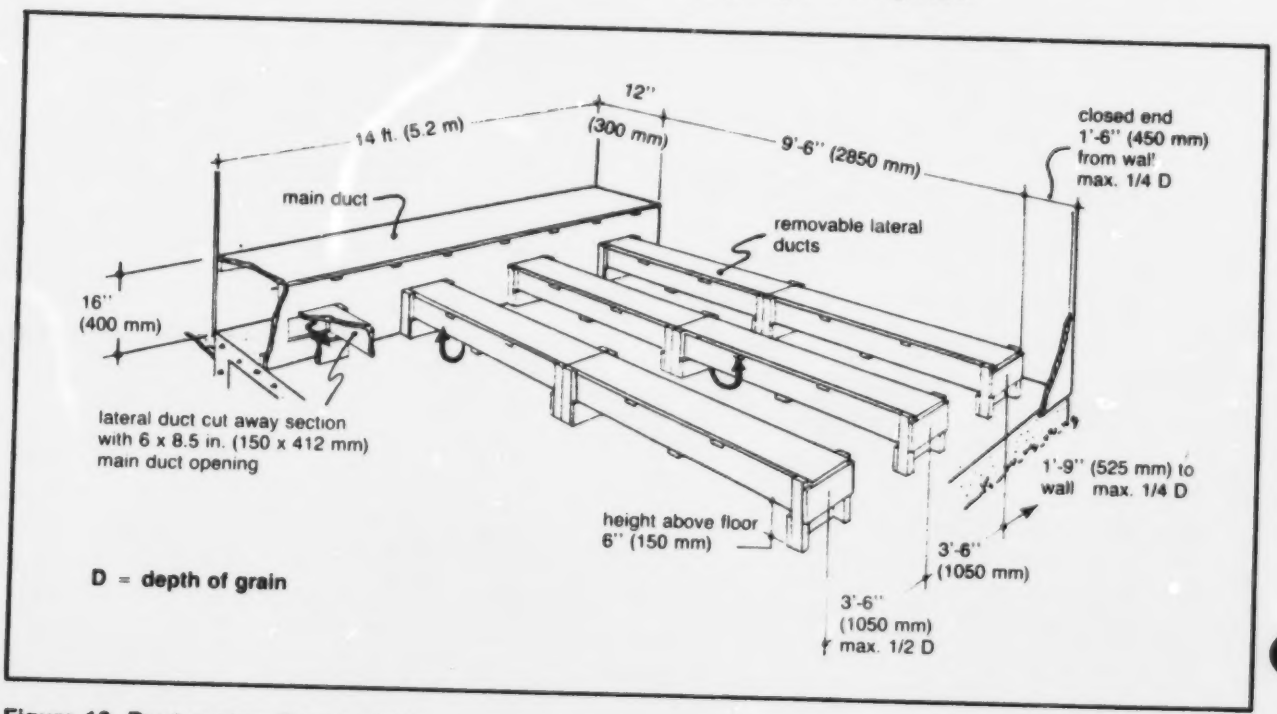


Figure 19. Duct system for wood bin

Air Distribution Systems for Hopper Bottom Bins

There are a variety of air distribution systems available for natural air drying in hopper bottom bins (Fig. 20). The majority of these units do not meet the guidelines set out in Table 3. However, field experience indicates these units have reasonably good air distribution patterns; those with ducts located in the upper part of the hopper rely on air leakage around the outlet port to allow air down through the grain in the hopper.

The following points should be considered when selecting an air distribution system:

- largest perforated (or outlet) area (as close as possible to requirements provided in Table 3)

- ease of installation

- ease of operation

- adequate support for suspended components

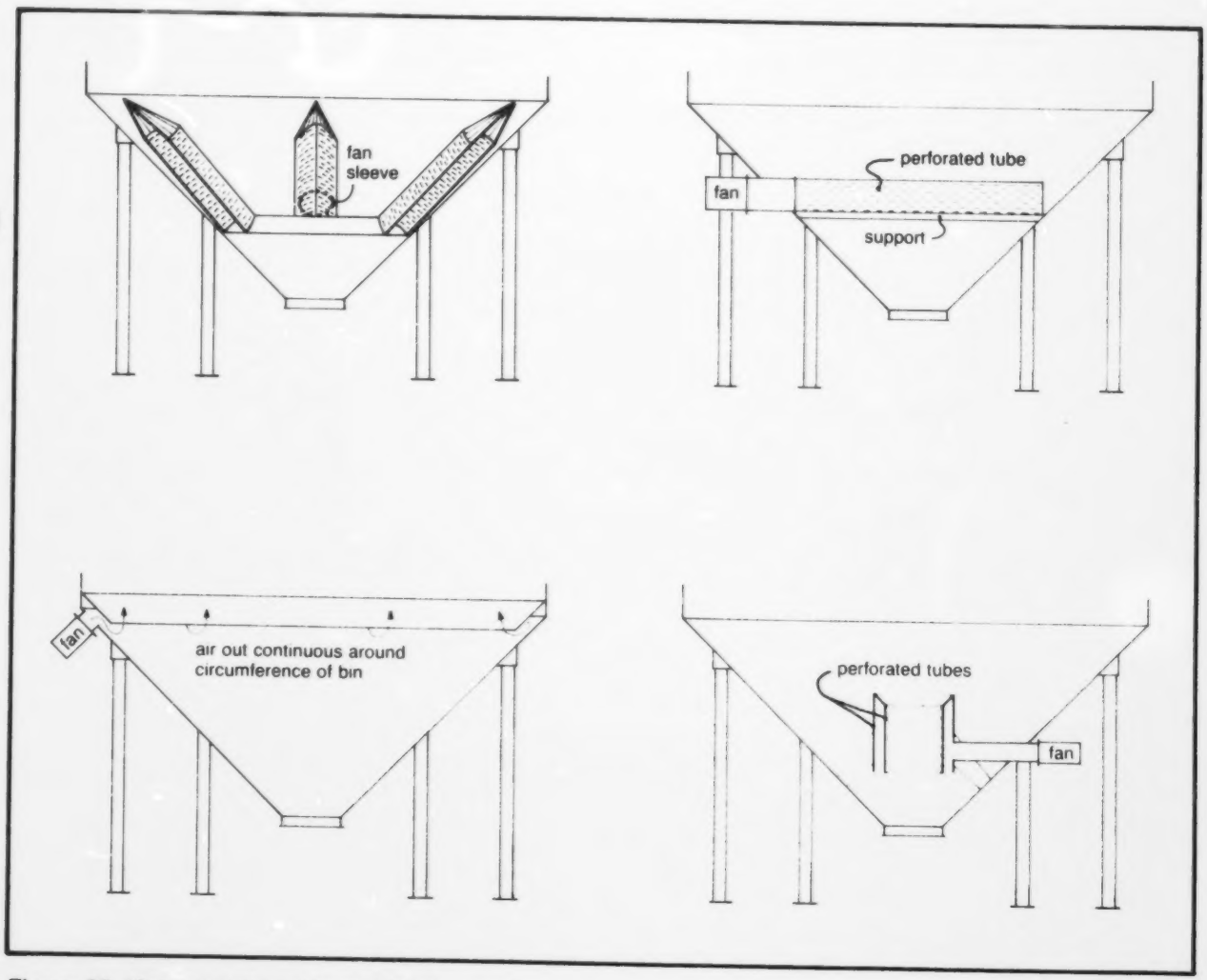


Figure 20. Hopper bottom bin distribution systems

Example Worksheet

Bin (from Appendix 1)

Make _____ Model _____

Diameter 22 feet ~~or metres~~

Height 15 feet ~~or metres~~

Volume 4575 bushels ~~or cubic metres~~

Grain

Type Barley

Maximum Moisture Content 20 %

Maximum Temperature 30 °C

Fan Requirement

Airflow rate 1 cfm/bu. ~~or l/s·m^3~~ (Zone 1)

(Determine airflow rate from Table 2 using the maximum moisture content and temperature of the grain and location of bin.)

Airflow 1 x 4575 = 4575 cfm ~~or l/s~~ (airflow rate x bin volume)

Expected Static Pressure 7 inches of Water ~~or Pa~~

(Determine from Fig. 8 using the airflow rate, depth of grain and either the coarse seed or small seed section.)

Fans Selected

Select a fan that will deliver the required airflow at the expected static pressure from the "Fan Performance" handi-fact or manufacturer specifications.

	A	B	C	D
Make:	Various	Options		
Type:	Centrifugal	Centrifugal		
Power:	10hp	10hp		
Size:	3450 rpm	3450 rpm		
Cost:				

Component Sizing

Minimum cross sectional duct area 3 ft.^{2} ~~or m^2~~

Minimum perforated floor area 150 ft.^{2} ~~or m^2~~

Minimum roof vent area 4.5 ft.^{2} ~~or m^2~~

(Obtain all sizes from Table 3, refer to plan S-711)

Example Worksheet

Bin (from Appendix 1)

Make _____ Model _____

Diameter 5.8 ~~feet or~~ metres

Height 4.7 ~~feet or~~ metres

Volume 123.5 ~~bushels or~~ cubic metres

Grain

Type Wheat

Maximum Moisture Content 17 %

Maximum Temperature 25 °C

Fan Requirement

Airflow rate 10 ~~cfm/bu. or~~ L/s m^3 (Zone 1)

(Determine airflow rate from Table 2 using the maximum moisture content and temperature of the grain and location of bin.)

Airflow 10 X 123.5: 1235 ~~cfm or~~ L/s (airflow rate x bin volume)

Expected Static Pressure 1500 ~~inches of Water or~~ Pa

(Determine from Fig. 8 using the airflow rate, depth of grain and either the coarse seed or small seed section.)

Fans Selected

Select a fan that will deliver the required airflow at the expected static pressure from the "Fan Performance" handi-fact or manufacturer specifications.

	A	B	C	D
Make:	←	Various Options		→
Type:	Axial	Centrifugal	Centrifugal	Centrifugal
Power:	9-10 hp	5 hp	4.5 hp	5 hp
Size:	24" dia.	3450 rpm	18" outlet	3450 rpm
Cost:				

Component Sizing

Minimum cross sectional duct area 0.17 ~~ft^2 or~~ m^2

Minimum perforated floor area 8.3 ~~ft^2 or~~ m^2

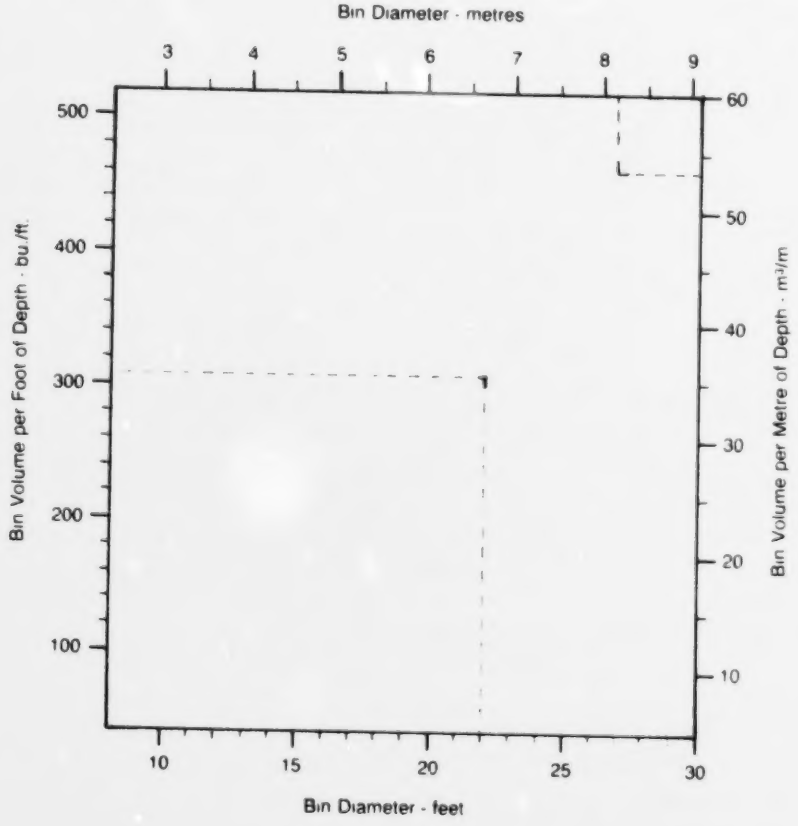
Minimum roof vent area 0.25 ~~ft^2 or~~ m^2

(Obtain all sizes from Table 3, refer to plan S-711)

Appendix 1. Common bin sizes

Model	Diameter		Height				Capacity			
			to eave		overall		to eave		heaped	
	ft.	(m)	ft.	(m)	ft.	(m)	bu.	(m^3)	bu.	(m^3)
Behlen										
12	12.2	(3.7)	10.0	(3.0)	16.7	(5.1)	935	(33.0)	1195	(42.0)
12	12.2	(3.7)	15.0	(4.6)	21.7	(6.6)	1400	(49.3)	1660	(58.5)
16	15.8	(4.8)	10.0	(3.0)	17.3	(5.2)	1570	(55.3)	2045	(72.0)
16	15.8	(4.8)	15.0	(4.6)	22.3	(6.8)	2350	(82.7)	2825	(99.5)
16	15.8	(4.8)	20.0	(6.1)	27.3	(8.3)	3150	(110.9)	3600	(126.8)
22	22.0	(6.7)	10.0	(3.0)	19.0	(5.8)	3040	(107.0)	4180	(147.2)
22	22.0	(6.7)	15.0	(4.6)	24.0	(7.3)	4560	(160.6)	5700	(200.8)
22	22.0	(6.7)	20.0	(6.1)	29.0	(8.8)	6080	(214.2)	7220	(254.3)
22	22.0	(6.7)	25.0	(7.6)	34.0	(10.4)	7600	(267.7)	8740	(307.9)
22	22.0	(6.7)	30.0	(9.1)	39.0	(11.9)	9120	(321.3)	10260	(361.4)
27	26.8	(8.2)	10.0	(3.0)	19.3	(5.9)	4510	(158.9)	6260	(220.5)
27	26.8	(8.2)	15.0	(4.6)	24.3	(7.4)	6770	(238.5)	8515	(300.0)
27	26.8	(8.2)	20.0	(6.1)	29.3	(8.9)	9025	(317.9)	10770	(379.4)
27	26.8	(8.2)	25.0	(7.6)	34.3	(10.5)	11280	(397.3)	13025	(458.8)
Butler										
1411	14.0	(4.3)	11.0	(3.6)	14.6	(4.4)	1354	(47.7)	1540	(54.2)
1415	14.0	(4.3)	14.7	(4.5)	18.3	(5.6)	1820	(64.1)	2030	(71.5)
1418	14.0	(4.3)	18.3	(5.6)	22.0	(6.7)	2290	(80.7)	2500	(88.1)
1811	18.0	(5.5)	11.0	(3.6)	15.7	(4.8)	2240	(78.9)	2650	(93.3)
1815	18.0	(5.5)	14.7	(4.5)	19.3	(5.9)	2990	(105.3)	3435	(121.0)
1818	18.0	(5.5)	18.3	(5.6)	23.0	(7.0)	3725	(131.2)	4215	(148.5)
1822	18.0	(5.5)	22.0	(6.7)	26.7	(8.1)	4480	(557.8)	4995	(176.0)
2118	21.0	(6.4)	18.3	(5.6)	24.3	(7.4)	5070	(178.6)	5900	(207.8)
2126	21.0	(6.4)	25.7	(7.8)	31.7	(9.7)	7120	(250.8)	8030	(282.9)
2718	27.0	(8.2)	18.3	(5.6)	26.0	(7.9)	8380	(295.2)	10000	(352.3)
2722	27.0	(8.2)	22.0	(6.7)	29.8	(9.1)	10075	(354.9)	11800	(415.7)
2726	27.0	(8.2)	25.7	(7.8)	33.5	(10.2)	11770	(414.6)	13550	(477.3)
Chief-Westland										
4-3	12.4	(3.8)	8.3	(2.5)	12.0	(3.7)	800	(28.1)	950	(33.5)
4-4	12.4	(3.8)	11.0	(3.4)	14.8	(4.5)	1060	(37.3)	1215	(42.8)
4-5	12.4	(3.8)	13.8	(4.2)	17.5	(5.3)	1332	(46.9)	1480	(52.1)
4-6	12.4	(3.8)	16.5	(5.0)	20.3	(6.2)	1593	(56.1)	1750	(61.6)
4-7	12.4	(3.8)	19.3	(5.9)	23.0	(7.0)	1863	(65.6)	2012	(70.9)
5-3	15.5	(4.7)	8.3	(2.5)	13.1	(4.0)	1252	(44.1)	1554	(54.7)
5-4	15.5	(4.7)	11.0	(3.4)	15.8	(4.8)	1650	(58.1)	1961	(69.1)
5-5	15.5	(4.7)	13.8	(4.2)	18.6	(5.7)	2082	(73.3)	2383	(83.9)
5-6	15.5	(4.7)	16.5	(5.0)	21.3	(6.5)	2490	(87.7)	2791	(98.3)
5-7	15.5	(4.7)	19.3	(5.9)	24.1	(7.3)	2912	(102.6)	3214	(113.2)
6-3	18.6	(5.7)	8.3	(2.5)	14.2	(4.3)	1803	(63.5)	2337	(82.3)
6-4	18.6	(5.7)	11.0	(3.4)	16.9	(5.2)	2390	(84.2)	2924	(103.0)
6-5	18.6	(5.7)	13.8	(4.2)	19.7	(6.0)	2998	(105.6)	3532	(124.4)
6-6	18.6	(5.7)	16.5	(5.0)	22.4	(6.8)	3585	(126.3)	4119	(145.1)
6-7	18.6	(5.7)	19.3	(5.9)	25.2	(7.7)	4193	(147.7)	4727	(166.5)
7-4	21.7	(6.6)	11.0	(3.4)	18.0	(5.5)	3553	(125.2)	4115	(145.0)
7-5	21.7	(6.6)	13.8	(4.2)	20.8	(6.3)	4080	(143.7)	4943	(174.1)
7-6	21.7	(6.6)	16.5	(5.0)	23.5	(7.2)	4879	(171.9)	5742	(202.3)
7-7	21.7	(6.6)	19.3	(5.9)	26.3	(8.0)	5707	(201.0)	6570	(231.4)
8-5	24.8	(7.6)	13.8	(4.2)	21.8	(6.6)	5330	(187.8)	6618	(233.1)
8-6	24.8	(7.6)	16.5	(5.0)	24.6	(7.5)	6377	(224.5)	7677	(270.4)
8-7	24.8	(7.6)	19.3	(5.9)	27.3	(8.3)	7455	(262.6)	8742	(307.9)
Twister										
	13.8	(4.2)	11.8	(3.6)	15.8	(4.8)	1410	(49.7)	1570	(55.3)
	13.8	(4.2)	14.8	(4.5)	18.8	(5.7)	1770	(62.3)	1930	(68.0)
	13.8	(4.2)	17.8	(5.4)	21.8	(6.6)	2130	(75.0)	2290	(80.7)
	17.3	(5.6)	11.8	(3.6)	17.4	(5.3)	2672	(94.1)	3125	(110.1)
	17.3	(5.6)	14.8	(4.5)	20.4	(6.2)	3355	(118.2)	3810	(134.2)
	17.3	(5.6)	17.8	(5.4)	23.4	(7.1)	4037	(142.2)	4492	(158.2)
	17.3	(5.6)	20.8	(6.3)	26.4	(8.0)	4720	(166.3)	5175	(182.3)

Model	Diameter		Height to eave		Height overall		Capacity to eave		Capacity heaped	
	ft.	(m)	ft.	(m)	ft.	(m)	bu.	(m³)	bu.	(m³)
Westeel-Rosco										
144	13.8	(4.2)	10.3	(3.1)	14.3	(4.4)	1272	(42.4)	1431	(50.4)
145	13.8	(4.2)	12.8	(3.9)	16.8	(5.1)	1530	(53.9)	1730	(60.9)
146	13.8	(4.2)	15.3	(4.7)	19.3	(5.9)	1830	(64.5)	2020	(71.5)
194	19.1	(5.8)	10.3	(3.1)	15.8	(4.8)	2360	(82.1)	2885	(101.6)
195	19.1	(5.8)	12.8	(3.9)	18.3	(5.6)	2932	(103.2)	3458	(121.8)
196	19.1	(5.8)	15.3	(4.7)	20.8	(6.3)	3505	(122.5)	4030	(142.0)
197	19.1	(5.8)	17.8	(5.4)	23.3	(7.1)	4079	(142.7)	4603	(162.1)
198	19.1	(5.8)	20.3	(6.2)	25.8	(7.9)	4651	(163.8)	5176	(182.3)
Wide-Corr										
21-3	20.9	(6.4)	11.2	(3.4)	17.4	(5.3)	3072	(108.2)	3781	(133.2)
21-4	20.9	(6.4)	14.8	(4.5)	21.0	(6.4)	4060	(142.0)	4769	(168.0)
21-5	20.9	(6.4)	18.5	(5.6)	24.7	(7.5)	5074	(178.7)	5783	(203.7)
21-6	20.9	(6.4)	22.2	(6.8)	28.4	(8.7)	6090	(214.5)	6798	(239.5)
21-7	20.9	(6.4)	25.8	(7.9)	32.0	(9.8)	7077	(249.3)	7786	(274.3)
24-3	23.9	(7.3)	11.2	(3.4)	18.1	(5.5)	4018	(141.4)	5049	(177.9)
24-4	23.9	(7.3)	14.8	(4.5)	21.7	(6.6)	5309	(187.0)	6340	(223.3)
24-5	23.9	(7.3)	18.5	(5.6)	25.4	(7.7)	6636	(233.8)	7668	(270.1)
24-6	23.9	(7.3)	22.2	(6.8)	29.1	(8.9)	7964	(280.5)	8995	(316.9)



Bin volume vs diameter

Examples

22 ft diameter bin
15 ft depth
= 305 x 15 = 4575 bu

8.2 m diameter bin
7.8 m depth
= 53 x 7.8 = 413.4 m³

Appendix 2. Wire size for single phase motors — allowing 2 percent voltage drop

Motor Hp	Rated Voltage	Full Load Amp.	Wire Size for Given Distance in Feet (Metres)						
			50(15)	75(23)	100(30)	150(46)	200(61)	250(76)	300(91)
1/2	115	9.8	14	12	10	8	6	6	4
3/4		13.8	12	10	8	6	6	4	4
1/2	230	4.9	14	14	14	14	12	12	10
3/4		6.9	14	14	14	12	12	10	10
1		8	14	14	14	12	10	10	10
1½		10	14	14	12	10	10	8	8
2		12	12	12	12	10	10	8	8
3		17	10	10	10	8	8	6	6
5		28	10	10	8	6	6	4	4

Note — The wire size for a given distance in feet includes the wire from the service panel to the load.

Example — To operate a 3 hp. motor on 230 volts at 150 ft. from the service panel, use #8 wires from the service panel to the outlet and from the outlet to the load.

Appendix 3. Static pressure developed for various grain depths and airflow rates

Grain Depth		Approximate Static Pressure* - Pa (Inches of Water)					
		Small Seeds			Coarse Seeds		
metre	feet	7 L/s•m² 0.5 cfm/bu.	13 L/s•m² 1.0 cfm/bu.	20 L/s•m² 1.5 cfm/bu.	7 L/s•m² 0.5 cfm/bu.	13 L/s•m² 1.0 cfm/bu.	20 L/s•m² 1.5 cfm/bu.
	6	<1	2	2.5	<1	1	1.5
2		<250	500	650	<250	250	400
	8	1.5	2.5	4	1	2	2.5
3		500	1000	1500	400	750	1100
	10	2	4	6	1.5	3	4.5
	12	3	5	8	2	4	6
4		1000	1800	2500	600	1200	1800
	14	4	7	11	2.5	5	8
	16	5	10	15	4	7	10
5		1250	2500	4000	1000	1800	2600
	18	6.5	12	19	4.5	9	13
6		1800	3750	>5000	1250	2700	3800
	20	7	15	>20	5	11	16

Note: - The SI units for pressure is the Pascal (Pa); 250 Pa ≈ 1 inch of water
- For static pressures that fall above the dotted line select either an axial or centrifugal fan; for static pressures that fall below the dotted line a centrifugal fan is recommended.

* These are approximate expected static pressures; the actual static pressure developed may vary by as much as 50 percent

Worksheet

Bin (from Appendix 1)

Make _____ Model _____

Diameter _____ feet or metres

Height _____ feet or metres

Volume _____ bushels or cubic metres

Grain

Type _____

Maximum Moisture Content _____ %

Maximum Temperature _____ °C

Fan Requirement

Airflow rate _____ cfm/bu. or L/s m^3 (Zone ___)

(Determine airflow rate from Table 2 using the maximum moisture content and temperature of the grain and location of bin.)

Airflow _____ cfm or L/s (airflow rate x bin volume)

Expected Static Pressure _____ inches of water or Pa

(Determine from Fig. 8 using the airflow rate, depth of grain and either the coarse seed or small seed section.)

Fans Selected

Select a fan that will deliver the required airflow at the expected static pressure from the "Fan Performance" handi-fact or manufacturer specifications.

	A	B	C	D
Make:	_____	_____	_____	_____
Type:	_____	_____	_____	_____
Power:	_____	_____	_____	_____
Size:	_____	_____	_____	_____
Cost:	_____	_____	_____	_____

Component Sizing

Minimum cross sectional duct area _____ $ft.^2$ or m^2

Minimum perforated floor area _____ $ft.^2$ or m^2

Minimum roof vent area _____ $ft.^2$ or m^2

(Obtain all sizes from Table 3, refer to plan S-711)

Worksheet

Bin (from Appendix 1)

Make _____ Model _____

Diameter _____ feet or metres

Height _____ feet or metres

Volume _____ bushels or cubic metres

Grain

Type _____

Maximum Moisture Content _____ %

Maximum Temperature _____ °C

Fan Requirement

Airflow rate _____ cfm/bu. or L/s m^3 (Zone ___)

(Determine airflow rate from Table 2 using the maximum moisture content and temperature of the grain and location of bin.)

Airflow _____ cfm or L/s (airflow rate x bin volume)

Expected Static Pressure _____ inches of Water or Pa

(Determine from Fig. 8 using the airflow rate, depth of grain and either the coarse seed or small seed section.)

Fans Selected

Select a fan that will deliver the required airflow at the expected static pressure from the "Fan Performance" handi-fact or manufacturer specifications.

	A	B	C	D
Make:	_____	_____	_____	_____
Type:	_____	_____	_____	_____
Power:	_____	_____	_____	_____
Size:	_____	_____	_____	_____
Cost:	_____	_____	_____	_____

Component Sizing

Minimum cross sectional duct area _____ $ft.^2$ or m^2

Minimum perforated floor area _____ $ft.^2$ or m^2

Minimum roof vent area _____ $ft.^2$ or m^2

(Obtain all sizes from Table 3, refer to plan S-711)